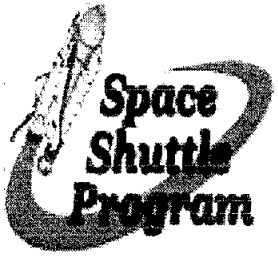
# EXTERNAL TANK




SPACE SHUTTLE PROGRAM
Space Shuttle Projects Office (MSFC)
NASA Marshall Space Flight Center, Huntsville, Alabama


# STS-103/ET-101
# Flight Readiness Review

## External Tank Project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# Overview



- **ET-101 Highlights**
  - Fourth ET to fly with SRB camera coverage
- **Limited life component status - All items within required life**
- **Processing anomalies**
  - ET/SRB Cross-Strap Harness Failures - Discussed by USA
  - ET-106 GO2 2" Disconnect Bent Poppet Stem Missing Chrome Plating
    - STS-103/ET-101 hardware assessment - Discussed by BNA
- **Requirement Changes**
  - LH2 Tank Changes for SSME Block II Implementation
- **Changes resulting from Intertank thrust panel foam loss**
  - Increased Intertank Foam Venting
- **Special Topic**
  - Weld Instruction Card (WIC) Certification
  - Heat Treat of Flexible Joint Ball
- **Open work/paper - No constraints to flight**

## LH2 Tank Changes for SSME Block II Implementation



- **Change**
  - Revised LH2 tank vent/relief valve acceptance pressure requirements and post proof x-ray requirements

- **Background**
  - Advanced high pressure fuel turbopump in the Block II SSME has increased preburner temperature spikes during engine start transient causing reduced turbine blade life
    - PSIG action resulted in decision to modify the Block II start transient by increasing the LH2 inlet pressure at engine start command
    - Required modification of the ET pre-pressurization control bands and LH2 ullage pressure ICD
  - Raised pre-pressurization control band will be used only on flights with three Block II SSMEs
    - ***Not required for STS-103/ET-101***

- **Description**
  - Revised ET GH2 vent/relief valve requirements for higher pre-press level - No design change

| | **Was** | **Now** |
|---|---|---|
| • *Relief pressure* | 36.0 ±1.0 psig | 36.75+0.25/-0.00 psig |
| • *Reseat pressure* | 34.0 psig | 34.25 psig |

  - Revised post proof weld x-ray requirements for LH2 tank circumferential welds

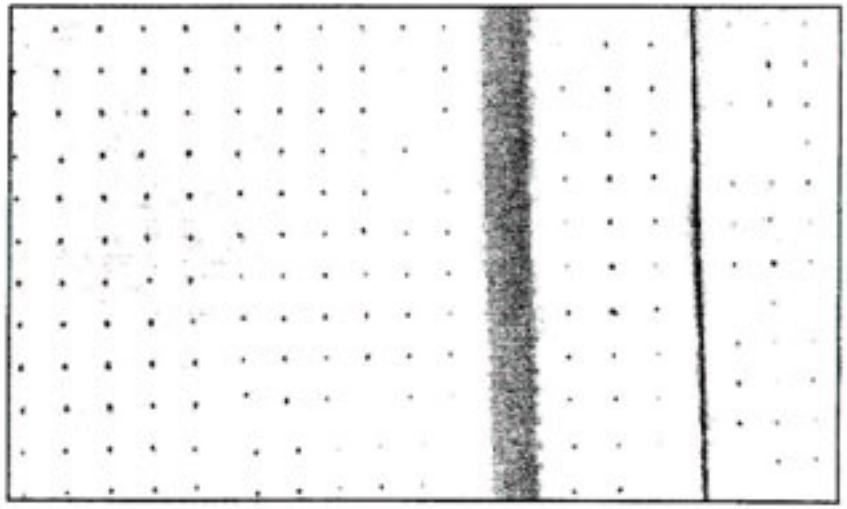
- **Basis for Certification**
  - **Test and Inspection**
    - Successful completion of LH2 tank proof test
    - Performed post proof weld x-ray requirements on additional 215 inches of LH2 tank circumferential welds
    - No change to critical test demonstrated LH2 tank Factor of Safety
    - Raised LH2 tank pre-press band was demonstrated on STS-91 tanking test
      - Narrow band with 0.5 second GHe bursts was demonstrated
      - Pre-press level demonstrated was 0.3 psi lower than planned for use with three Block II SSMEs

  - **Analysis**
    - Propulsion analysis shows LH2 tank ullage pressure will be within LCC limits during pre-press
    - Structural analysis shows overall critical factor of safety unchanged
      - Factor of Safety for critical circumferential welds (failure mode: ultimate tension)

| *Weld ID* | *Required* | *Was* | *Now* |
|---|---|---|---|
| • LH2 Tank H4 | 1.25 | 1.51 | 1.45 |
| • LH2 Tank H5 | 1.25 | 1.49 | 1.42 |

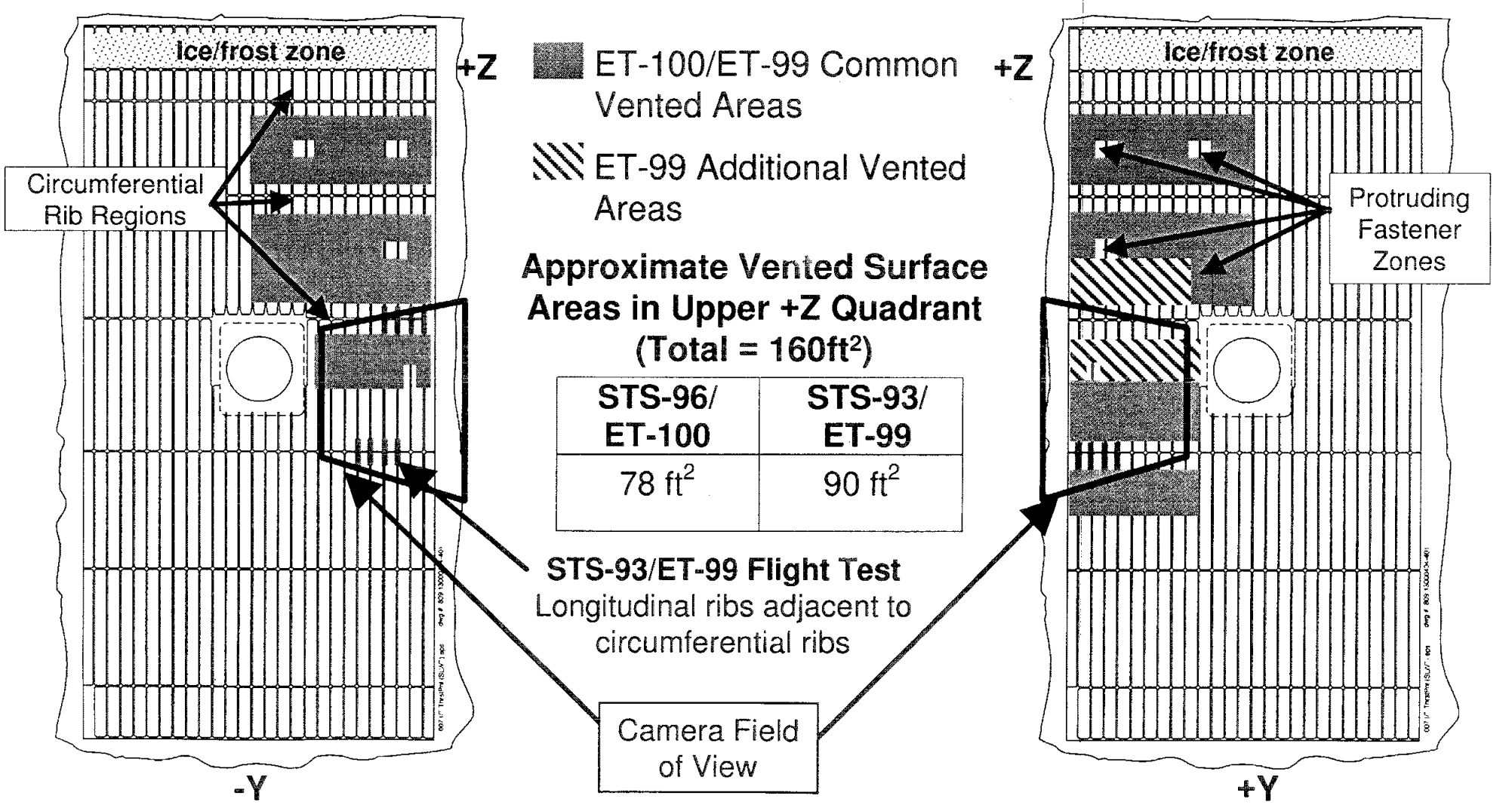
- **Change**
  - Increased vented portions of the Intertank thrust panel and skin/stringer panel foam

- **Background**
  - Post flight inspection of STS-87 revealed out-of-family damage to the Orbiter tiles caused by foam loss from the ET Intertank thrust panel
  - A rigorous test program has demonstrated that foam venting reduces popcorn-type debris
  - Vented foam configuration has been certified by test and analysis to do no harm
  - Venting of Intertank foam implemented on STS-96/ET-100 and STS-93/ET-99
  - Review of SRB video following STS-96/ET-100 showed less debris with vented foam
  - Based upon STS-96/ET-100 data and additional analysis, area of Intertank thrust panel foam to be vented was increased for STS-93/ET-99

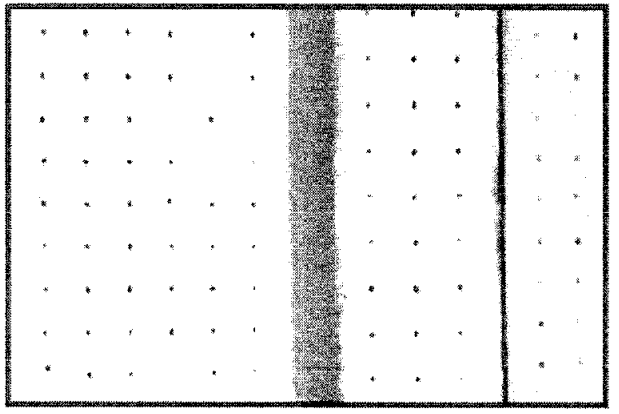


*Typical Vented Foam Configuration*

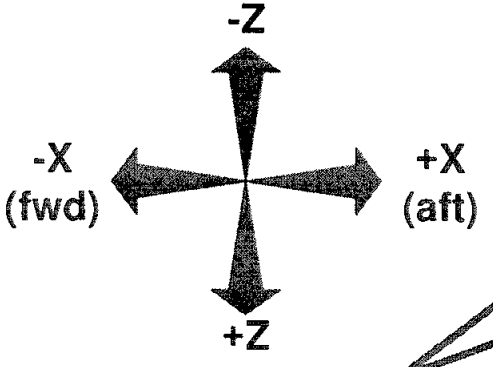
- **Background (continued)**

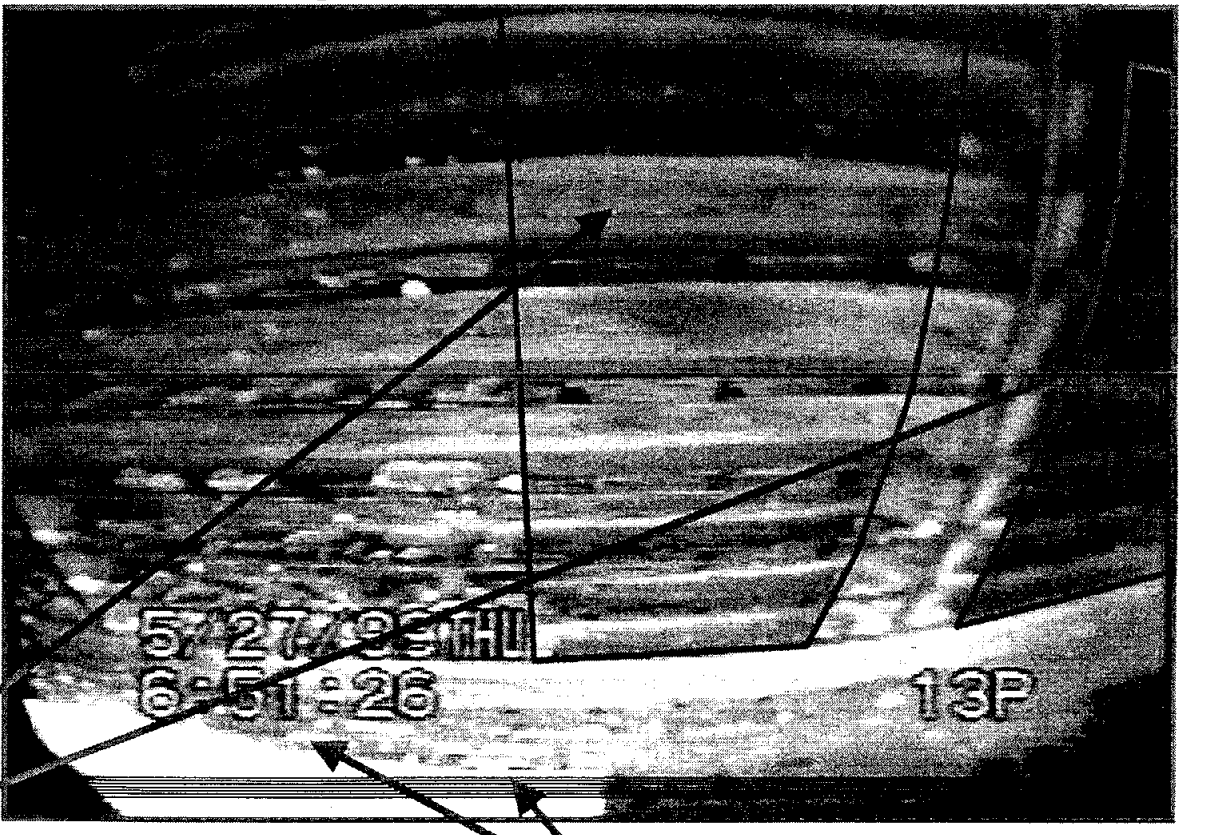


- **Background (continued)**
  - Review of STS-93/ET-99 SRB flight video confirmed performance enhancement realized through foam venting
    - Popcorning exhibited on Intertank skin/stringer foam



*Typical Vented Foam Configuration*



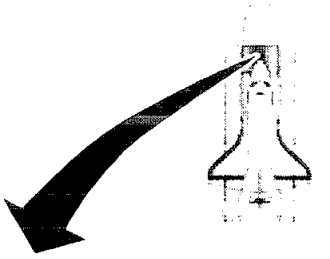

Vented Area on STS-96/ET-100 +Y Thrust Panel

Foam Loss on Skin/Stringer Areas

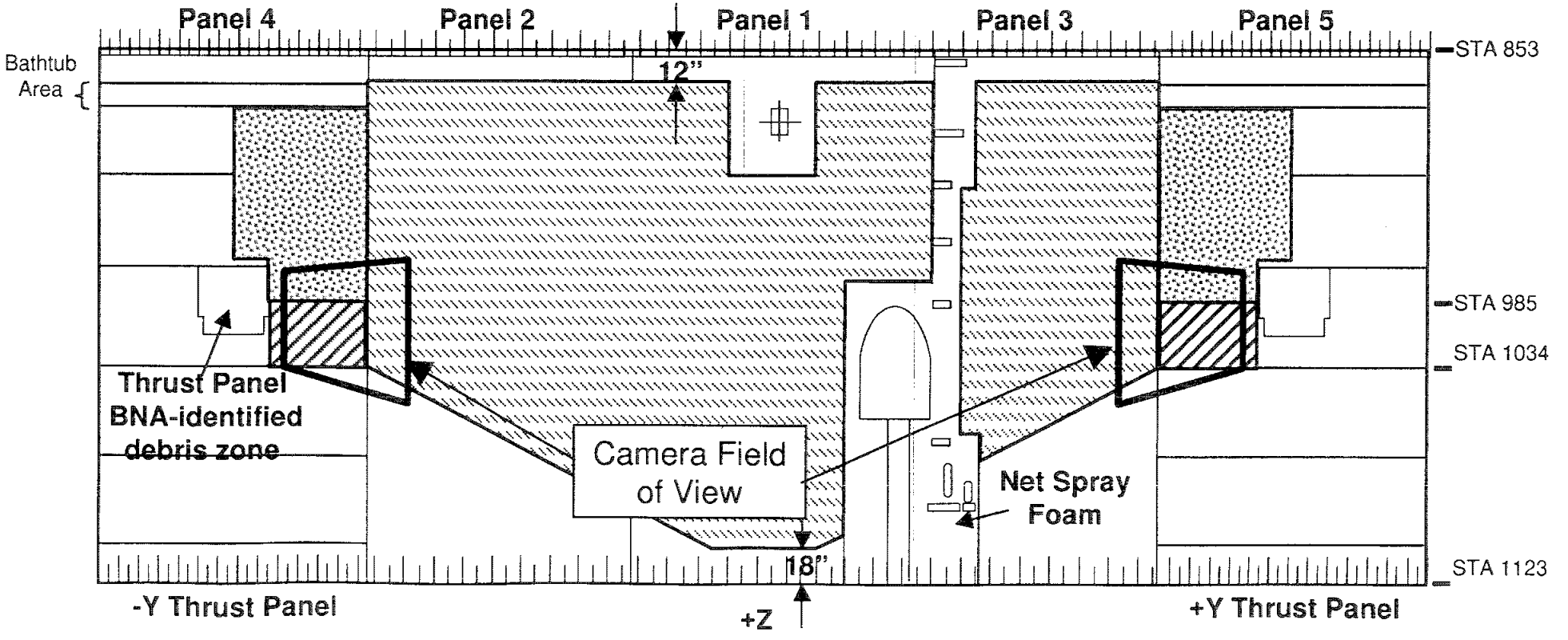
# Intertank Foam Venting



- **Description of Change**
  - Perform venting of Intertank foam areas
    - Combination of BNA-identified debris zone and areas of observed foam loss
    - Areas of potential ice-formation and unmachined foam excluded
      - Vented thrust panel area in BNA-identified debris zone = 90 ft²
      - Vented thrust panel area outside of BNA-identified debris zone = 12 ft²
      - Vented skin/stringer areas = 725 ft²
      - Unvented BNA-identified debris zone = 36 ft² (8 ft² bathtubs, 18 ft² ramps, 10 ft² cryo)



*Panels 6-8 omitted*



# Thrust Panel and Skin/Stringer Panel Foam Venting



- **Basis for Certification**
  - Test
    - Tests performed in different test beds following various environmental conditioning
    - Results from all performance testing show that vented foam performs as well as or better than the non-vented foam configuration and measurably reduces foam loss
  - Similarity
    - Vented foam configuration similar to configuration flown on STS-96/ET-100 and STS-93/ET-99

| Certification Test | No. of Tests | Humidity | Salt Fog | Vented |
|---|---|---|---|---|
| **Vented Foam Certification Testing** | | | | |
| **Mechanical Properties/Acceptance Testing** | | | | |
| Density | 200 | | | X |
| Bond Tension | 540 | X | X | X |
| Flatwise Tension | 540 | X | X | X |
| Lap Shear | 360 | X | | X |
| Plug Pulls | 144 | | X | X |
| Flexure (Ribbed panels) | 24 | X | | X |
| **Thermal Properties** | | | | |
| Thermal Conductivity | 24 | X | X | X |
| **Flight Verification** | | | | |
| Hot Gas - Flat Panels, Machined foam | 20 | X | X | X |
| Hot Gas - Rib Panels, Machined foam | 63 | X | X | X |
| Hot Gas - Skin/stringer, Machined foam | 7 | X | | X |
| Thermal/Vacuum, Flat Panels, Machined foam | 40 | X | X | X |
| Thermal/Vacuum, Single Rib Panels, Machined foam | 14 | | | X |
| Thermal/Vacuum, Rib Panels, Machined foam | 24 | X | X | X |
| Thermal/Vacuum, Skin/stringer, Machined foam | 8 | X | | X |
| Wind Tunnel (AEDC), Machined foam | 4 | | | X |
| Vibro/Acoustic Test (DOE C Addendum Testing) | 6 | X | | X |
| **Process Verification/Acceptance** | | | | |
| Full-Scale Process Pathfinder (GVTA) | 1 | | | X |

- **Basis for Certification**
  - Popcorning performance of additional rib and skin/stringer configurations similar to that of previously successfully vented thrust panel configurations
  - NASA/LMMSS IFA team reviewed test results indicates that venting of rib locations adjacent to circumferential rib ramps and skin/stringer panel areas are certified "to do no harm"
  - No safety of flight concerns

# Weld Instruction Card (WIC) Certification



- **Issue**
  - During a recent weld schedule review, it was determined that several of the weld schedules were incorrectly certified

- **Background**
  - Weld certification requirements are established through Engineering process requirements documents
    - Certification requirements verify that weld schedules produce acceptable weld strengths and quality
    - Requirements are then restated and implemented in the "how to" manufacturing process documents
  - Ambiguity of the weld process documents and reliance on institutional knowledge led to instances of incomplete testing for weld certification

- **Background**
  - Performed LMMSS Quality and Engineering review of all "as-built" ET welds
    - Discrepancies were documented on non-conformance documents (NCDs)
    - Each NCD was individually analyzed, dispositioned and approved by LMMSS and NASA/MSFC
    - When necessary, additional welded panels were fabricated and tested
    - All discrepant weld schedules were reviewed to the correct certification condition
    - Weld operations were suspended until discrepancies were resolved
  - Process escapes led to end-to-end weld process review
    - LMMSS and NASA/MSFC conducted a review (October - present) of all ET welding processes
      - No significant findings that required immediate implementation prior to weld operations resuming
      - 49 findings that require resolution:
        - Procedural enhancements
        - Communication/information flow down
        - Adherence to command media
        - Training enhancement opportunities
      - One additional issue identified during the NASA/LMMSS Review
        - Concern for design strength of welds (cryogenic properties) due to effect of weld parameter variations

- **STS-103/ET-101 Rationale for Flight**
  - Team reviewed the 49 findings noted during the review and determined that there were no concerns for ET-101
  - Team also conducted an assessment of the weld strength and determined that adequate rationale existed for ET-101 clearance:
    - Weld-by-weld reviews
    - Review of as-built parameter charts
    - ET-101 as-delivered weld tests
    - Parameter range test data
    - Wide panel and confidence panel data
    - Fracture property review
    - Proof test stresses and history
    - Flight stress analysis
  - LMMSS and NASA/MSFC Review Team concluded that there was no safety of flight concerns
    - Resolution of remaining findings are not considered as constraints to flight
    - Root cause identified as lack of clear process requirements and lack of command media that controls of weld certifications
      - Corrective action plan in work

## Heat Treat of Flexible Joint Ball



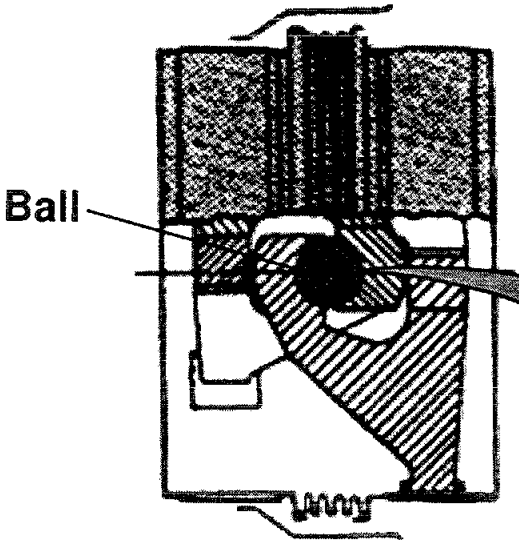
- **Issue**
  - Incorrect heat treat of Inconel 718 Ball Strut Tie-Rod Assembly (BSTRA) balls

- **Background**
  - 24 BSTRA flexible joints on each ET
    - 19 balls in the GO2 and GH2 pressurization line joints
    - 5 balls in the LO2 feedline joints

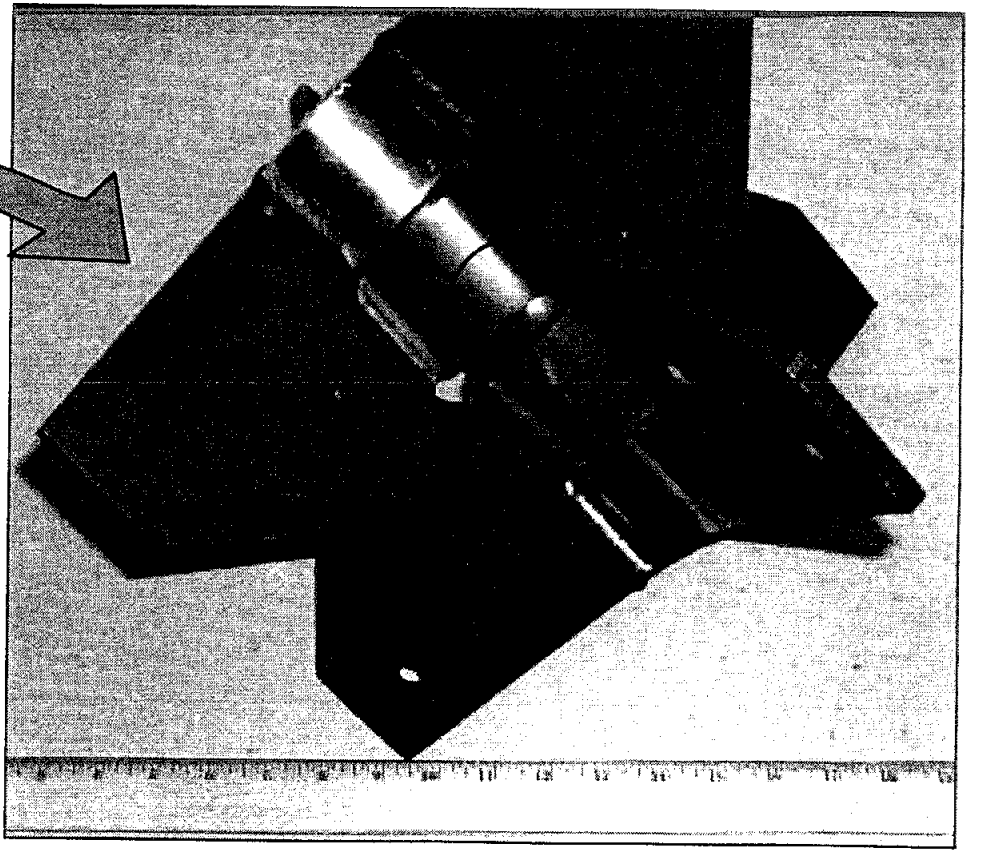
  - Both diameter balls affected by incorrect heat treat
    - Specification for Inconel Sheet/Tubing required for heat treatment of BSTRA balls
  - BSTRA subcontractor recently determined that their heat treating vendor had incorrectly age hardened a large number of balls to a combination of the specifications for Inconel Sheet/Tubing and Inconel Bars/Forgings
    - ET feedline and pressurization line supplier discovered discrepancy during a review of data pack at LMMSS' request
  - Test coupons accompanying suspect balls showed that the parts exceeded specification requirements
    - Tested at 40-41 Rockwell "C" (Rc) hardness
    - Specification requires minimum of 37 Rc

# Heat Treat of Flexible Joint Ball





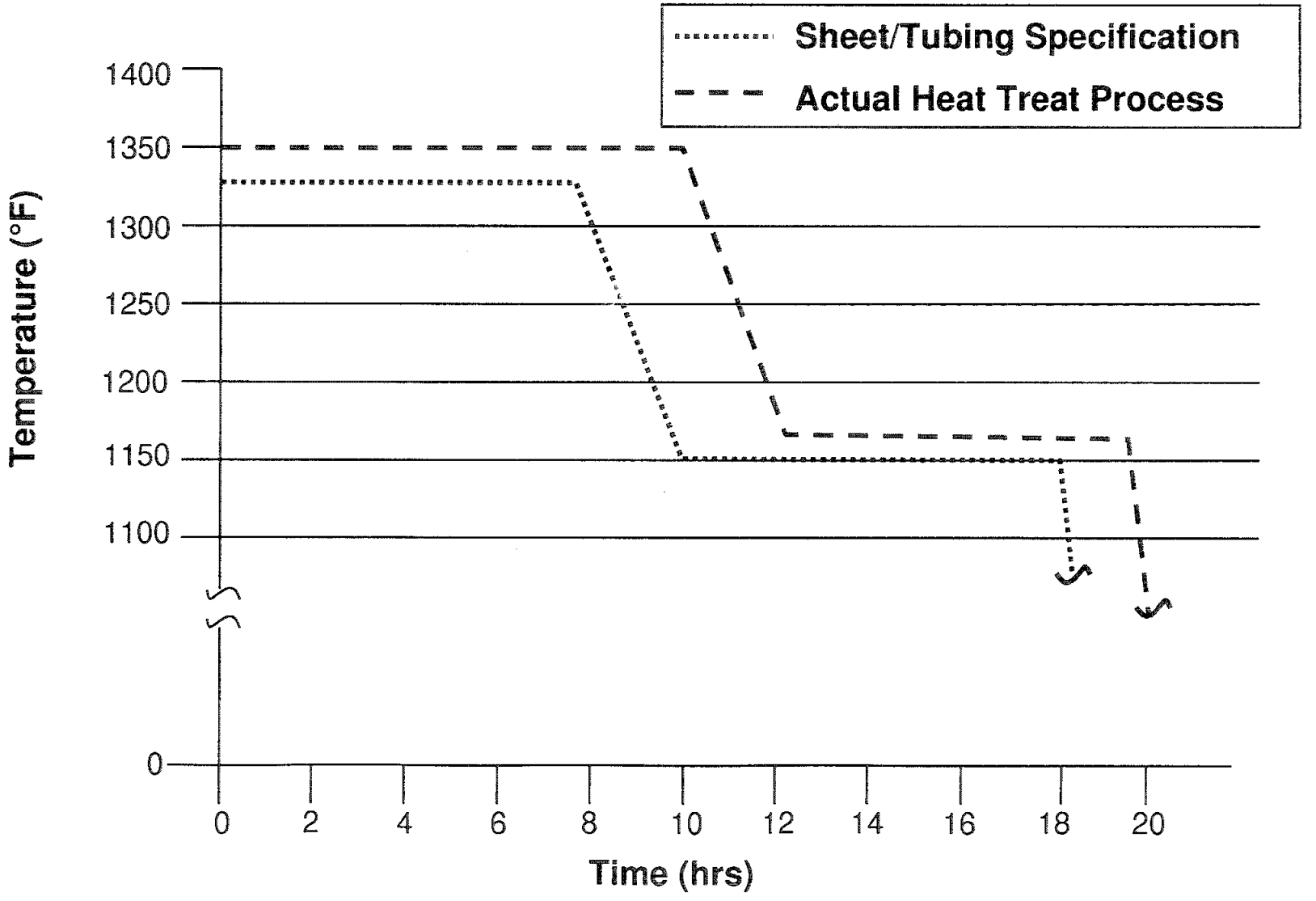

**Line Flexible Joint**
(X-Section)



**Ball Strut Tie-Rod Assembly**
(LO2 Feedline 2.24" dia. ball shown)

# Heat Treat of Flexible Joint Ball





- **Discussion**
  - Suspect balls are also installed on the STS-103/ET-101 pressurization lines
  - Review of build paper showed that balls of this pedigree have previously flown from the same heat treat lot with same hardness values
    - No anomalies noted
  - LMMSS and NASA/MSFC metallurgists reviewed the differences in heat treat cycle and determined that the structural integrity of the BSTRA is unaffected

- **Rationale for Flight**
  - Test
    - Qualification test remains valid
  - Analysis
    - Significant stresses are compression
      - Minor differences in hardness values not sufficient to affect compression strength
      - Design FS > 4.0
  - Acceptance
    - Test coupons had final acceptance values within acceptable limits
      - Rockwell "C" hardness = 40-41 vs requirement of 37
      - Hardness values for properly treated balls = 39-47 Rc

# The External Tank, ET-101, is hereby certified and ready for STS-103 flight pending completion/closure of open and planned work

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